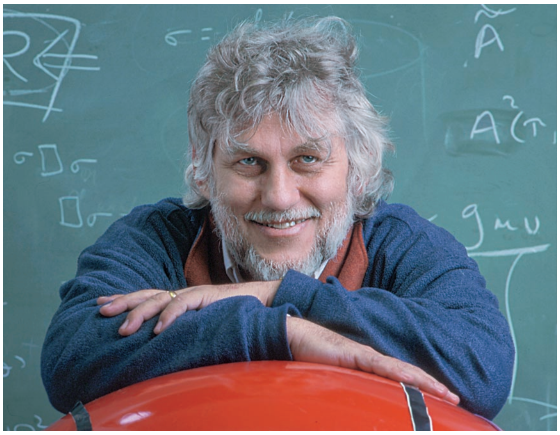
CANADIANS IN PHYSICS

Gravity: A Matter of Time

William George Unruh was born in Winnipeg, the son of a high school physics teacher. “As a boy I loved looking at the pictures in my father’s physics textbooks,” he recalls. “They aroused my curiosity about how the world works.” He attended the University of Manitoba and then Princeton University, where he received his Ph.D. Today, he is a professor of physics and astronomy at the University of British Columbia and a Fellow of the Canadian Institute for Advanced Research.



Dr. Unruh with the beach ball that he sometimes uses to help explain the concept of gravity.

Dr. Unruh explains that, according to Albert Einstein, “The rate at which time flows can change from place to place, and it is this change in the flow of time that causes the phenomenon we usually refer to as gravity.” Dr. Unruh’s work focusses on understanding aspects of Einstein’s theories. “For example,” he says, “Since matter can influence time and matter influences gravity, which is just the variable flow of time, the very measuring instruments we use to measure time can change time. While this is not important in most situations, it becomes very important in trying to decide how the universe operates; for example, in understanding black holes.” Dr. Unruh explains that, in black holes, the structures of space and time collaborate, creating regions through which even light cannot travel.

“All of physics is now described in terms of field theories,” Dr. Unruh points out. “However, we also experience the world in terms of particles. Since fields exist everywhere at all times, part of my work has been trying to understand the particulate nature of fields. Probably my best known work is showing that the particle nature of fields depends on the observer’s state of motion. If an observer is accelerated through a region that seems to be empty of particles to an observer at rest, that region will, to the accelerated observer, appear to be filled with a hot bath of particles. Thus, the existence or non-existence of particles in a field can depend on how the observer moves as he or she observes that field. The effect is extremely small, but it is there.”

Another area in which Dr. Unruh works is gravity wave detection. A gravity wave might be called a “vibration of space and time.” It is caused by the acceleration of masses; for example, of black holes around each other. The techniques that Dr. Unruh and others have developed will be important to the future refinement of gravity wave detectors now being built in the states of Louisiana and Washington, as well as elsewhere in the world.

Since magnetic monopoles are not known to exist, it is not practical to try to define magnetic field intensities in a way that is analogous to the definitions of electric and gravitational fields. The most practical way to describe magnetic field intensity at this point is to relate it to the effect of a magnetic field on a current-carrying wire, which you studied in previous science courses. The following steps show you how to relate the **magnetic field intensity**, B, to the force, $\vec{F}_B$, exerted by the magnetic field on a length, l, of wire carrying a current, I.

- Write the equation describing the force on a current-carrying conductor in a magnetic field when the direction of the current is perpendicular to the magnetic field.

$$\vec{F}_B = \vec{I}\,l\,\vec{B}$$

- Rearrange the equation to solve for the magnetic field intensity.

$$\vec{B} = \frac{\vec{F}}{\vec{I}l}$$

- The SI unit of magnetic field intensity is the tesla, T. Substitute SI units for the symbols in the equation above.

$$\mathrm{T} = \frac{\mathrm{N}}{\mathrm{A \cdot m}} \text{ or}$$

$$\text{tesla} = \frac{\text{newton}}{\text{ampere} \cdot \text{metre}}$$

The above relationship states that if each metre of a conductor that is carrying a current of one ampere experiences a force of one newton due to the presence of a magnetic field that is perpendicular to the direction of the current, the magnitude of the magnetic field is one tesla.

Fields near Point Sources

The definition and accompanying equation that you learned for electric field strength, $\vec{E} = \vec{F}_Q/q$, is a general definition. If you know the force on a charge due to an electric field, you can determine the electric field intensity without knowing anything about the source of the field. It is convenient, however, to develop equations that describe the electric field intensity for a few common, special cases, such as point charges.

- Write the equation describing the magnitude of the force on a test charge, q_t, that is a distance, r, from a point charge, q.

$$|\vec{F}_Q| = k\frac{qq_t}{r^2}$$

- Write the general definition for the electric field intensity.

$$\vec{E} = \frac{\vec{F}_Q}{q_t}$$

- Substitute the expression for force into the above equation and simplify.

$$|\vec{E}| = \frac{k\frac{q\cancel{q_t}}{r^2}}{\cancel{q_t}}$$

$$|\vec{E}| = k\frac{q}{r^2}$$

ELECTRIC FIELD INTENSITY NEAR A POINT CHARGE

The electric field intensity a distance away from a point charge is the product of Coulomb's constant and the charge, divided by the square of the distance from the charge. The direction of the field is radially outward from a positive point charge and radially inward toward a negative point charge.

$$|\vec{E}| = k\frac{q}{r^2}$$

Quantity	Symbol	SI unit
electric field intensity	$\vec{E}$	$\frac{\text{N}}{\text{C}}$ (newtons per coulomb)
Coulomb's constant	k	$\frac{\text{N}\cdot\text{m}^2}{\text{C}^2}$ (newton · metres squared per coulomb squared)
source charge	q	C (coulombs)
distance	r	m (metres)

Unit Analysis

$$\frac{\text{newton}\cdot\text{metre}^2}{\text{coulomb}^2}\cdot\frac{\text{coulomb}}{\text{metre}^2} = \frac{\text{newton}}{\text{coulomb}}$$

$$\frac{\text{N}\cdot\cancel{\text{m}^2}}{\text{C}^{\cancel{2}}}\cdot\frac{\cancel{\text{C}}}{\cancel{\text{m}^2}} = \frac{\text{N}}{\text{C}}$$

Note: This equation applies only to the field surrounding an isolated point charge.

SAMPLE PROBLEMS

Field Intensity near a Charged Sphere

1. **What is the electric field intensity at a point 30.0 cm from the centre of a small sphere that has a positive charge of 2.0×10^{-6} C?**

Conceptualize the Problem

- At any point outside of a *charged sphere*, the *electric field* is the same as it would be if the charge was *concentrated at a point* at the *centre* of the sphere.
- The *electric field* is related to the source *charge* and *distance*.
- The *direction* of the field is the direction in which a *positive charge would move* if it was placed at that point in the field.

Identify the Goal

The electric field intensity, $\vec{E}$

Identify the Variables and Constants

Known	**Implied**	**Unknown**
$q = +2.0 \times 10^{-6}$ C	$k = 9.0 \times 10^9 \dfrac{\text{N}\cdot\text{m}^2}{\text{C}^2}$	$\vec{E}$
$r = 0.30$ m		

Develop a Strategy

Find the field intensity by using the equation for the special case of the field near a point charge.

$$|\vec{E}| = k\frac{q}{r^2}$$

Substitute the numerical values for charge and distance and solve.

$$|\vec{E}| = \left(9.0 \times 10^9 \frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)\left(\frac{2.0 \times 10^{-6}\ \text{C}}{(0.30\ \text{m})^2}\right)$$

$$|\vec{E}| = 2.0 \times 10^5 \frac{\text{N}}{\text{C}}$$

The direction is radially outward from the positive charge.

The electric field intensity is 2.0×10^5 N/C in a direction pointing directly away from the source charge.

Validate the Solution

Close to a charge of "average" magnitude, the field is expected to be quite strong. Check that the units cancel to give N/C.

$$\frac{\text{N}\cdot\cancel{\text{m}^2}}{\text{C}^{\cancel{2}}}\cdot\frac{\cancel{\text{C}}}{\cancel{\text{m}^2}} = \frac{\text{N}}{\text{C}}$$

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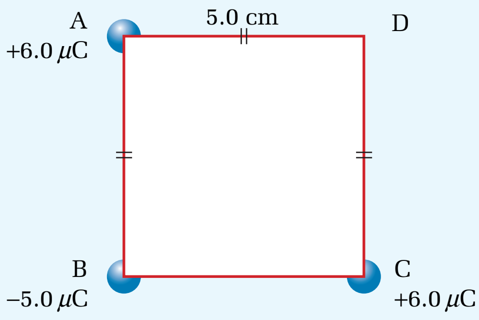
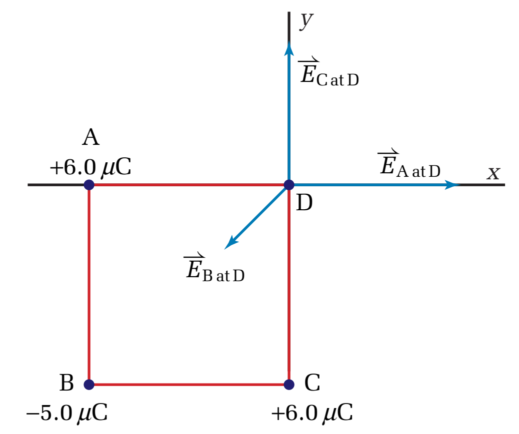
2. Three charges, A (+6.0 μC), B (–5.0 μC), and C (+6.0 μC), are located at the corners of a square with sides that are 5.0 cm long. What is the electric field intensity at point D?



Conceptualize the Problem

- Since field intensities are vectors they must also be *added vectorally*.
- The magnitude of the field vectors can be determined individually.
- Draw a *vector diagram* showing the *field intensity* vectors at point D and then superimpose an *x-y coordinate* system on the drawing, with the *origin* at point D.



Identify the Goal

The resultant electric field intensity, $\vec{E}$, at point D

Identify the Variables and Constants

Known	**Implied**	**Unknown**
$d_{AB} = d_{BC} = 5.0$ cm	$k = 9.0 \times 10^9 \dfrac{\text{N}\cdot\text{m}^2}{\text{C}^2}$	$\vec{E}_D$
$q_A = +6.0\ \mu$C		d_{BD}
$q_B = -5.0\ \mu$C		
$q_c = +6.0\ \mu$C		

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Develop a Strategy

Calculate the diagonal of the square by using the Pythagorean theorem.

Since the result is a distance, the negative root has no meaning. Use the positive root.

$$d_{BC}^2 = (5.0\ \text{cm})^2 + (5.0\ \text{cm})^2$$
$$d_{BC}^2 = 50.0\ \text{cm}^2$$
$$d_{BC} = \pm\sqrt{50.0\ \text{cm}^2}$$
$$d_{BC} = \pm 7.07\ \text{cm}$$
$$d_{BC} = 7.07\ \text{cm}$$

Calculate the magnitude of the electric field intensity of each of the given charges at point D, using the equation for the special case of the field intensity near a point charge.

$$|\vec{E}| = k\frac{q}{r^2}$$
$$|\vec{E}_{\text{A at D}}| = \left(9.0 \times 10^9\ \frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)\left(\frac{6.0 \times 10^{-6}\ \text{C}}{(0.050\ \text{m})^2}\right)$$
$$|\vec{E}_{\text{A at D}}| = 2.16 \times 10^7\ \frac{\text{N}}{\text{C}}$$
$$|\vec{E}_{\text{B at D}}| = \left(9.0 \times 10^9\ \frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)\left(\frac{5.0 \times 10^{-6}\ \text{C}}{(0.0707\ \text{m})^2}\right)$$
$$|\vec{E}_{\text{B at D}}| = 9.00 \times 10^6\ \frac{\text{N}}{\text{C}}$$
$$|\vec{E}_{\text{C at D}}| = \left(9.0 \times 10^9\ \frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)\left(\frac{6.0 \times 10^{-6}\ \text{C}}{(0.050\ \text{m})^2}\right)$$
$$|\vec{E}_{\text{C at D}}| = 2.16 \times 10^7\ \frac{\text{N}}{\text{C}}$$

Use the method of components to find the resultant electric field vector.

The angle between the x-axis and the vector for the field at point D due to charge B is 45°, because it points along the diagonal of a square.

***x*-components**

$$E_{(\text{A at D})x} = 2.16 \times 10^7\ \frac{\text{N}}{\text{C}}$$
$$E_{(\text{B at D})x} = -\left(9.00 \times 10^6\ \frac{\text{N}}{\text{C}}\right)\cos 45^\circ$$
$$E_{(\text{B at D})x} = -6.36 \times 10^6\ \frac{\text{N}}{\text{C}}$$
$$E_{(\text{C at D})x} = 0$$
$$E_{(\text{net})x} = 1.524 \times 10^7\ \frac{\text{N}}{\text{C}}$$

***y*-components**

$$E_{(\text{A at D})y} = 0$$
$$E_{(\text{B at D})y} = -\left(9.00 \times 10^6\ \frac{\text{N}}{\text{C}}\right)\sin 45^\circ$$
$$E_{(\text{B at D})y} = -6.36 \times 10^6\ \frac{\text{N}}{\text{C}}$$
$$E_{(\text{C at D})y} = 2.16 \times 10^7\ \frac{\text{N}}{\text{C}}$$
$$E_{(\text{net})y} = 1.524 \times 10^7\ \frac{\text{N}}{\text{C}}$$

Use the Pythagorean theorem to find the magnitude of the resultant vector.

$$|\vec{E}_{(\text{net})}|^2 = \left(E_{(\text{net})x}\right)^2 + \left(E_{(\text{net})y}\right)^2$$
$$|\vec{E}_{(\text{net})}|^2 = \left(1.524 \times 10^7\ \frac{\text{N}}{\text{C}}\right)^2 + \left(1.524 \times 10^7\ \frac{\text{N}}{\text{C}}\right)^2$$
$$|\vec{E}_{(\text{net})}|^2 = 4.6452 \times 10^{14}\left(\frac{\text{N}}{\text{C}}\right)^2$$
$$|\vec{E}_{(\text{net})}| = 2.1553 \times 10^7\ \frac{\text{N}}{\text{C}}$$
$$|\vec{E}_{(\text{net})}| \cong 2.2 \times 10^7\ \frac{\text{N}}{\text{C}}$$

Use the definition of the tangent function to find the direction of the electric field vector at point D.

$$\tan\theta = \frac{1.524 \times 10^7\ \frac{\text{N}}{\text{C}}}{1.524 \times 10^7\ \frac{\text{N}}{\text{C}}}$$
$$\tan\theta = 1.00$$
$$\tan\theta = \tan^{-1} 1.00$$
$$\tan\theta = 45^\circ$$

The electric field intensity at point D is 2.2×10^7 N/C at an angle of 45˚ counterclockwise from the positive *x*-axis.

Validate the Solution

Since two positive charges and one negative charge of similar magnitudes are creating the field, you would expect that the net field would be similar in magnitude to those created by the individual charges. The angle is 45˚ as predicted.

PRACTICE PROBLEMS

20. Calculate the electric field intensity at a point 18.0 cm from the centre of a small conducting sphere that has a charge of –2.8 μC.

21. The electric field intensity at a point 0.20 m away from a point charge is 2.8×10^6 N/C, directed toward the charge. What is the magnitude and sign of the charge?

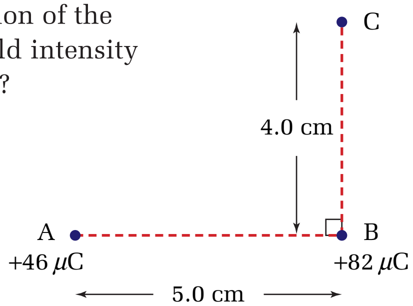
22. The electric field intensity at a point, P, near a spherical charge of 4.6×10^{-5} C, is 4.0×10^6 N/C. How far is point P from the centre of the charge?

23. How many electrons must be removed from a spherical conductor with a radius of 4.60 cm in order to make the electric field intensity just outside its surface 3.95×10^3 N/C?

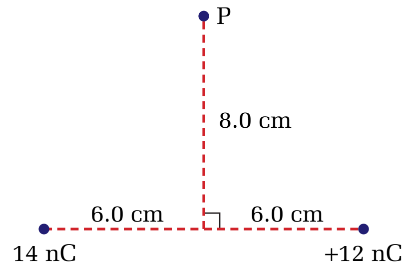
24. What is the electric field intensity at a point 15.2 cm from the centre of a sphere charged uniformly at –3.8 μC?

25. A charge of +7.4 μC establishes an electric field intensity at point M of 1.04×10^7 N/C. How far is point M from the centre of the charge?

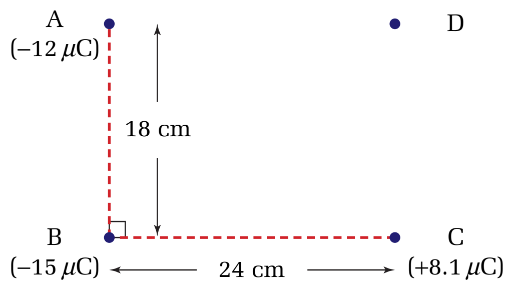
26. In the diagram, A and B represent small spherical charges of +46 μC and +82 μC, respectively. What is the magnitude and direction of the electric field intensity at point C ?



27. Determine the magnitude and direction of the electric field intensity at point P in the diagram.



28. The diagram shows three small charges at three corners of a rectangle. Calculate the magnitude and direction of the electric field intensity at the fourth corner, D.



29. Two point charges of –40.0 μC and +50.0 μC are placed 12.0 cm apart in air. What is the electric field intensity at a point midway between them?

30. Points A and B are 13.0 cm apart. A charge of +8.0 μC is placed at A and another charge of +5.0 μC is placed at B. Point P is located 5.0 cm from A and 12.0 cm from B. What is the magnitude and direction of the electric field intensity at P?

The approach taken above for electric fields can also be applied to gravitational fields. The following steps develop an expression for the gravitational field intensity near a point source. As stated previously, the field at any point outside of a spherical mass is the same as it would be if the mass was concentrated at a point at the centre of the sphere.

- Write the equation for the general definition of gravitational field intensity.

$$\vec{g} = \frac{\vec{F}_g}{m}$$

- Write the general equation for the gravitational force between two masses. Let m_1 be the source of a gravitational field and m_2 be any mass, m, in that field.

$$|\vec{F}_g| = G\frac{m_s m}{r^2}$$

- Substitute the expression for the force of gravity into the general expression for gravitational field intensity.

$$|\vec{g}| = \frac{G\frac{m_s \cancel{m}}{r^2}}{\cancel{m}}$$

$$|\vec{g}| = G\frac{m_s}{r^2}$$

GRAVITATIONAL FIELD INTENSITY NEAR A POINT MASS

The gravitational field intensity at a point a distance r from the centre of an object is the product of the universal gravitation constant and mass, divided by the square of the distance from the centre of the object. The direction of the gravitational field intensity is toward the centre of the object creating the field.

$$|\vec{g}| = G\frac{m_s}{r^2}$$

Quantity	**Symbol**	**SI unit**
gravitational field intensity	$\vec{g}$	$\frac{\mathrm{N}}{\mathrm{kg}}$ (newtons per kilogram)
universal gravitation constant	G	$\frac{\mathrm{N \cdot m^2}}{\mathrm{kg^2}}$ (newton · metres squared per kilogram squared)
mass of source of field	m_s	kg (kilograms)
distance from centre of source	r	m (metres)

Unit Analysis

$$\left(\frac{\text{newton} \cdot \text{metre}^2}{\text{kilogram}^2}\right)\left(\frac{\text{kilogram}}{\text{metre}^2}\right) = \left(\frac{\text{newton}}{\text{kilogram}}\right)$$

$$\frac{\mathrm{N} \cdot \cancel{\mathrm{m}^2}}{\mathrm{kg}^{\cancel{2}}} \times \frac{\cancel{\mathrm{kg}}}{\cancel{\mathrm{m}^2}} = \frac{\mathrm{N}}{\mathrm{kg}}$$

SAMPLE PROBLEM

Field Intensity near Earth

Calculate the gravitational field intensity at a height of 300.0 km from Earth's surface.

Conceptualize the Problem

- Since the point in question is *outside* of the *sphere* of Earth, the gravitational field there is the same as it would be if Earth's mass was concentrated at *a point at Earth's centre*. Therefore, the equation for the *gravitational field intensity* near a *point mass* applies.

Identify the Goal

The gravitational field intensity, $\vec{g}$

Identify the Variables and Constants

Known	Implied	Unknown
$h = 300.0\ \text{km}$	$G = 6.67 \times 10^{-11}\ \dfrac{\text{N}\cdot\text{m}^2}{\text{kg}^2}$	$\vec{g}$
	$r_E = 6.38 \times 10^6\ \text{m}$	
	$m_E = 5.98 \times 10^{24}\ \text{kg}$	

Develop a Strategy

Convert the height above Earth's surface into SI units and calculate the distance, r, from the centre of Earth.

$$h = 300.0\ \text{km} = 3.000 \times 10^5\ \text{m}$$
$$r = 3.000 \times 10^5\ \text{m} + 6.38 \times 10^6\ \text{m}$$
$$r = 6.68 \times 10^6\ \text{m}$$

Use the equation for the gravitational field intensity near a point source.

$$|\vec{g}| = G\frac{m_s}{r^2}$$

Substitute numerical values and solve.

$$|\vec{g}| = \frac{\left(6.67 \times 10^{-11}\ \frac{\text{N}\cdot\text{m}^2}{\text{kg}^2}\right)(5.98 \times 10^{24}\ \text{kg})}{(6.68 \times 10^6\ \text{m})^2}$$
$$|\vec{g}| = 8.9387\ \frac{\text{N}}{\text{kg}}$$
$$|\vec{g}| \cong 8.94\ \frac{\text{N}}{\text{kg}}$$

The gravitational field intensity 300.0 km from the surface of Earth is 8.94 N/kg.

Validate the Solution

You would expect the gravitational field intensity to be less than 9.81 N/kg at a great distance from Earth's surface.

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PRACTICE PROBLEMS

31. What is the gravitational field intensity at a distance of 8.4×10^7 m from the centre of Earth?
32. If the gravitational field intensity at the surface of Saturn is 26.0 N/kg and its mass is 5.67×10^{26} kg, what is its radius?
33. What is the acceleration due to gravity on the surface of Venus? ($m_{\text{Venus}} = 4.83 \times 10^{24}$ kg; $r_{\text{Venus}} = 6.31 \times 10^6$ m)
34. An astronaut drops a 3.60 kg object onto the surface of a planet. It takes 2.60 s to fall 1.86 m to the ground. If the planet is known to have a radius of 8.40×10^6 m, what is its mass?
35. What is the gravitational field intensity at a distance of 2.0 m from the centre of a spherical metal ball of mass 3.0 kg? (Calculate only the field due to the ball, not to Earth.)
36. Calculate the gravitational field intensity at a height of 560.0 m above the surface of the planet Venus. (See problem 33 for data.)
37. The planet Neptune has a gravitational field intensity of 10.3 N/kg at a height of 1.00×10^6 m above its surface. If the radius of Neptune is 2.48×10^7 m, what is its mass?

Field Lines

Electric Field Lines

You have learned that an electric field at a particular point can be represented by a vector arrow with a length that corresponds to the magnitude of the field intensity at a given point. The direction of the vector arrow indicates the direction of the electric field at that point.

If you wanted to visualize the entire field around an electric charge, however, you would need to draw a set of these vector arrows at many points in the space around the charge. This process would be very tedious and complicated, so an idea originally used by Michael Faraday has been adapted. Using this method, the vectors are replaced by a series of lines that follow the path that a tiny point charge would take if it was free to move in the electric field. These lines are called **electric field lines**. In the vicinity of a positive charge, such field lines would radiate straight out, just as a positive test charge would be pushed straight out.

The field lines are constructed so that, at every point on the line, the direction of the field is tangent to the line. The strength of the field is represented by the density of the lines. The farther apart these lines are, the weaker the field is. Figure 7.9 shows the electric field lines that represent the electric field in various charge arrangements.

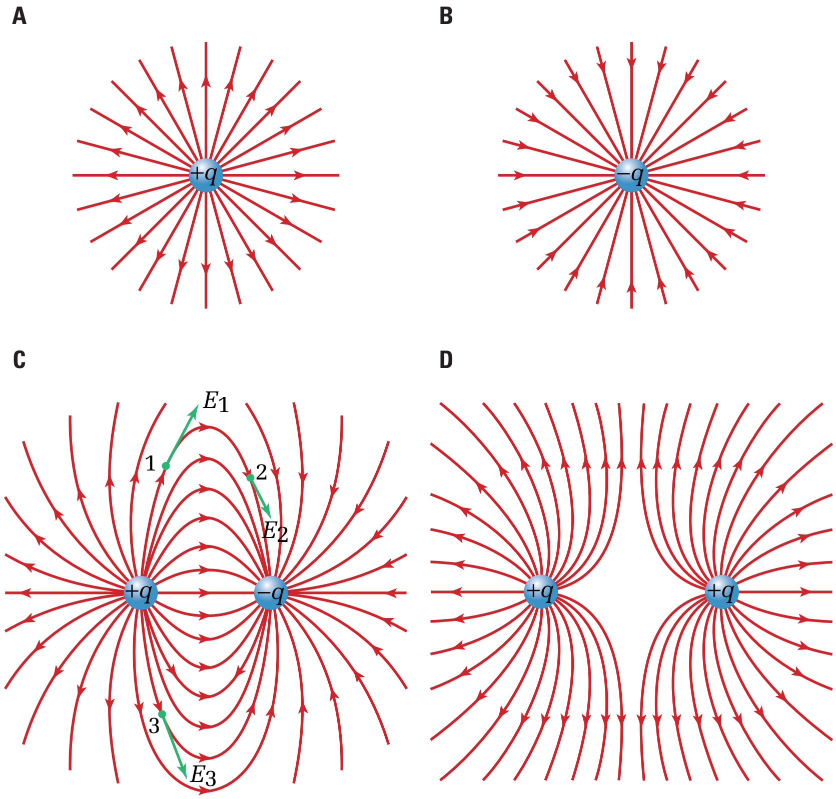

Figure 7.9 **(A)** The electric field lines from positive charge $+q$ are directed radially outward. **(B)** The electric field lines are directed radially inward toward negative point charge $-q$. **(C)** The electric field lines of an electric dipole are curved, and extend from the positive to the negative charge. At any point, such as 1, 2, or 3, the field created by the dipole is tangent to the line through the point. **(D)** The electric field lines for two identical positive point charges are shown. If both of the charges were negative, the directions of the lines would be reversed.

Note that when more than one electric source charge is present, the electric field vector at a point is the vector sum of the electric field attributable to each source charge separately. Since the field lines are often curved, this vector will be tangent to the field line at that point.

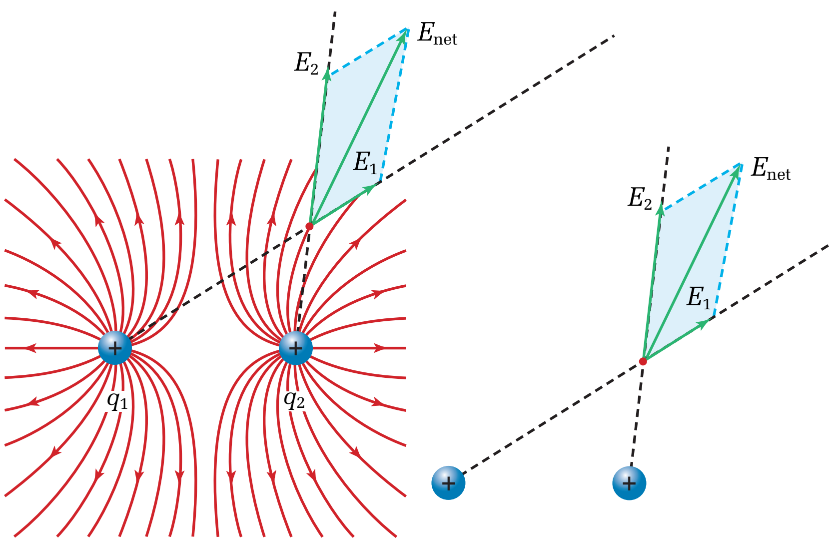

Figure 7.10 The electric field at a point near two positive charges

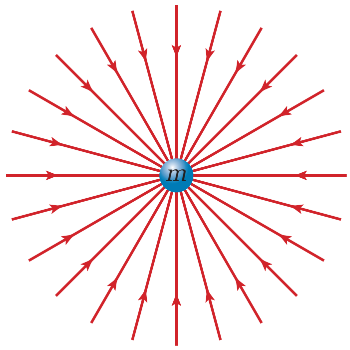

Figure 7.11 The gravitational field lines are directed radially inward toward a mass, *m*.

Gravitational Field Lines

Since the force of gravity is always attractive, the shape of **gravitational field lines** will resemble the electric field lines associated with a negative charge. Gravitational field lines will always point toward the centre of a spherical mass and arrive perpendicular to the surface.

Conceptual Problems

- Can there be a gravitational field diagram similar to the electric field in Figure 7.9 (D)? Explain.
- Sketch the gravitational field lines due to the two identical masses shown in the diagram here.

Magnetic Field Lines

Since there are no isolated magnetic poles (magnetic monopoles), the **magnetic field lines** have to be drawn so that they are associated with both poles of the magnet (magnetic dipole). The direction of the magnetic field at a particular location is defined as the direction in which the N-pole of a compass would point when placed at that location. The magnetic field lines leave the N-pole of a magnet, enter the S-pole, and continue to form a closed loop inside the magnet. The number of magnetic field lines, called the "magnetic flux," passing through a particular unit area is directly proportional to the magnetic field intensity. Consequently, flux lines are more concentrated at the poles of a magnet, where the magnetic field is greatest.

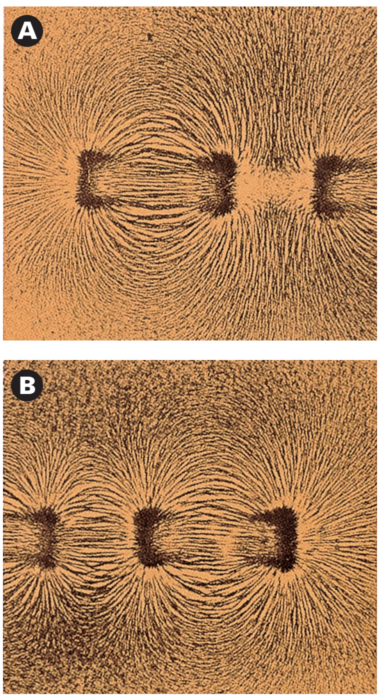

Figure 7.13 The field lines for **(A)** like poles and **(B)** unlike poles

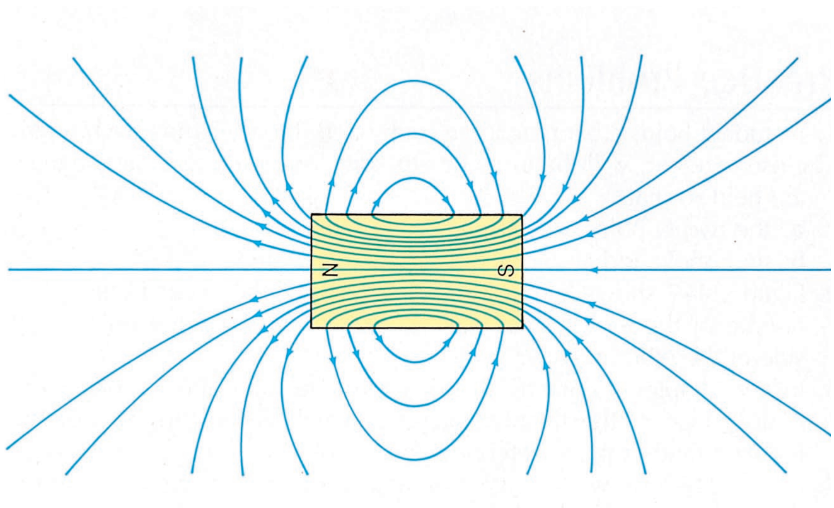

Figure 7.12 The magnetic field lines are closed loops leaving the N-pole of the magnet and entering the S-pole.

Conceptual Problems

- How does the magnetic dipole pattern compare with the electric field pattern of two opposite charges (an electric dipole)?
- What electrostatic evidence suggests that a water molecule is an electric dipole?
- What happens if you place a small bar magnet in a uniform magnetic field?
- What happens if you place a water molecule in a uniform electric field?

7.2 Section Review

1. **I** Place a strong bar magnet flat on a semi-rough surface, with the N-pole to the right. Place another bar magnet to the right of the first, but with its like N-pole to the left, suspended directly over the other N-pole. Adjust the top magnet until it balances. Now slide a piece of paper over the first magnet to hide it. Gently tap the suspended N-pole to start it vibrating vertically in space. What do your observations suggest about magnetic fields?
2. **K/U** What is the general definition for the electric field intensity at a distance r from a point charge q?
3. **I** Why is it not considered useful to define magnetic field intensity in the same way in which you defined the electric field intensity in question 2?
4. **C** Explain how you might calculate the gravitational field intensity at the various points along the path of a communication satellite orbiting Earth.
5. **K/U** In the vicinity of several point charges, how is the direction of the electric field intensity vector calculated?
6. **C** List four characteristics of electric field lines.

UNIT PROJECT PREP

A magnet held close to a refrigerator door is pulled toward the door. A ball rolls off a tabletop and is pulled toward the ground. Your hair sticks out in all directions after you remove a warm woollen cap. Each of these examples involve action at a distance. Forces are exerted without apparent contact.

- How does the use of fields help to explain action at a distance?
- Do descriptions of electric fields relate to descriptions of gravitational fields?
- Does an understanding of one type of field help with questions about another?